Feature Models with Dimensions in Space Missions

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METADEV

Content

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ProxyHands

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Disclaimer

- This is a work in progress
- Proof of Concepts and prototype quality TRL: 3-4

Technology Readiness Levels

1 — Basic Observations
2 — Technology Conceptualized
3 — Proof-of-Concept Validation
4 — Partial-Scale Prototype & Modeling
5 — Partial-Scale Prototype Validation
6 — Full-Scale Prototype Field Demonstration
7 — Full-Scale Prototype in Commercial Conditions
8 — Final Commercial Product Certification
9 — Final Commercial Product is Bank-Financeable

Feature Models

- Describes the pieces/capabilities in a system

- The potential configuration for a family of products

- In a tree structure
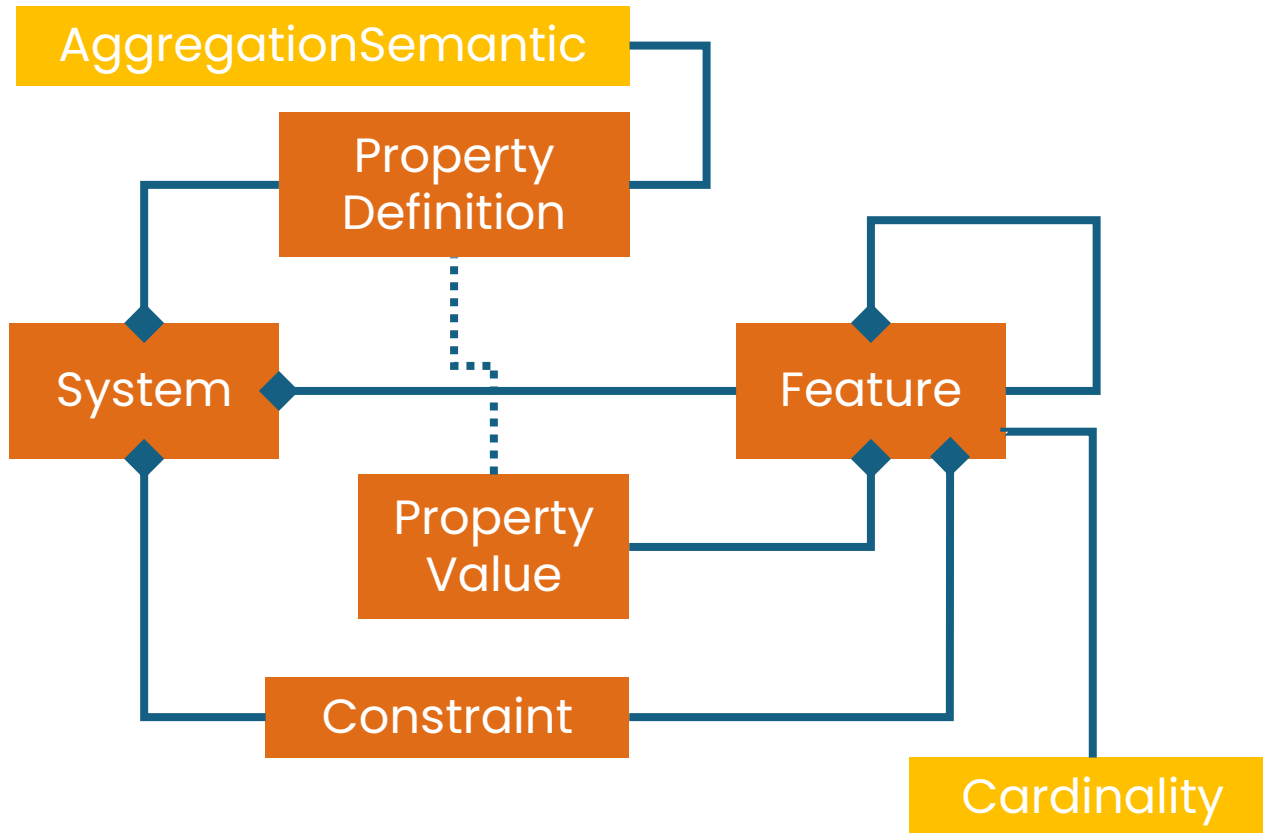
- With constrains f.e. cardinality
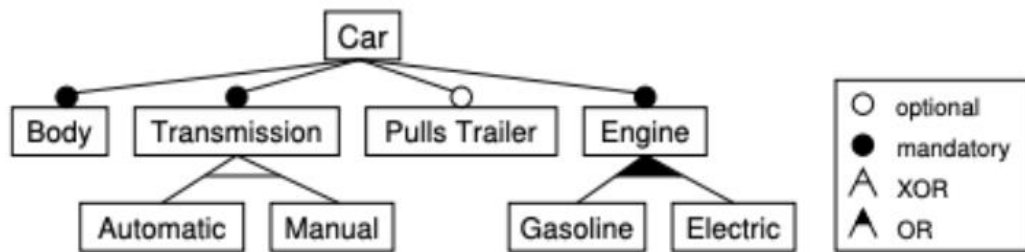
Dimensions

- **Physical systems have constraints like:**
  - Cost (EUR)
  - Weight (Kg)
  - Size (m)
  - Area (m^2)
  - Volume (m^3/l)
  - Power Generation/Consumptions (W)
  - Thermal (K) & pressure (N) tolerances
  - etc.
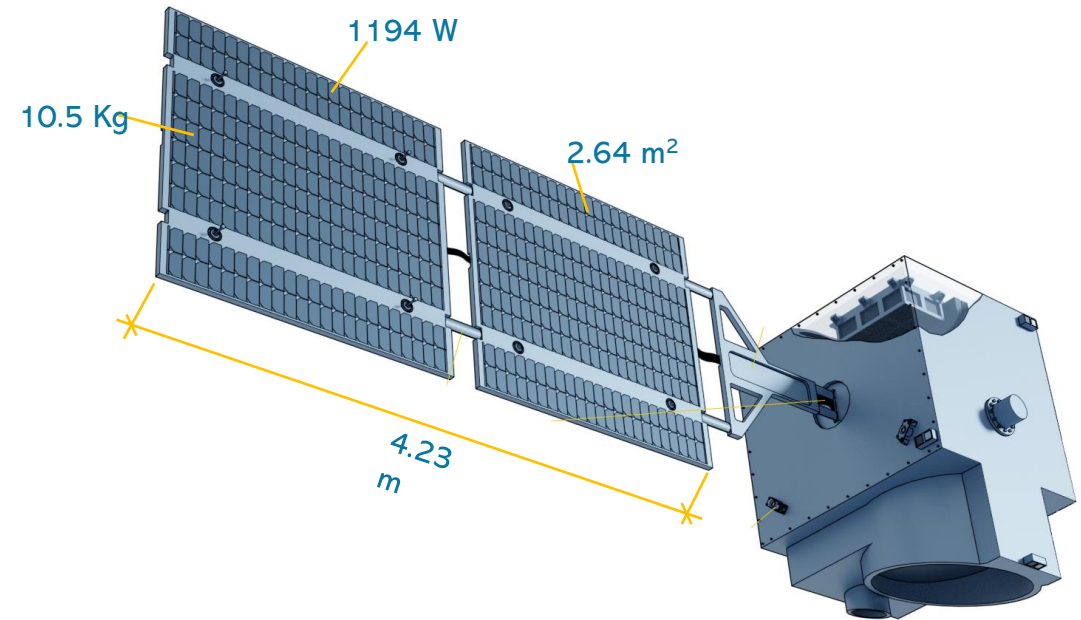
Base Metamodel for Feature Models with Dimensions

AggregationSemantic

Property Definition

System

Feature

Property Value

Constraint

Cardinality

```
class System {
    string Name;
    string Description;
    List<Feature> Features;
    List<PropertyDefinition> Properties;
    List<Constraint> Constraints;
}

class Feature {
    string Name;
    string Description;
    Cardinality Cardinality;
    int? minimum;
    int? maximum;
    Cardinality ItemsCardinality;
    int? itemsMinimum;
    int? itemsMaximum;
    List<Feature> Features;
    List<PropertyValue> Values;
}
```

Aggregation Semantic

- **Sum / Aggregate**   e.g.:   Cost, Weight

- **Maximum**   e.g.:   Height of pieces passing under a bridge

- **Minimum**   e.g.:   Max. Thermal tolerance of a set of components

- **Count**   e.g.:   Count of redundant systems for High-Availability.

Example. Car Configuration

```
Car Model-W Base:                              1500     Kg
  mandatory Version
  XOR Elegance                      40.000 EUR
        optional Air Condition        2000 EUR     2    Kg
        optional Seat Heaters          500 EUR     1    Kg
        optional Top Rack             1500 EUR     0.5  Kg
        optional Caravan Hitch        1000 EUR     0.2  Kg
        mandatory Wheels
                mandatory 17''                    80    Kg

  XOR Sport                         50.000 EUR
        mandatory Air Condition
        optional Seat Heaters          500 EUR
        optional Top Rack             1500 EUR
        optional Caravan Hitch        1000 EUR
        mandatory Wheels
            XOR 17''                     0 EUR    80     Kg
            XOR 19''                   500 EUR    90     Kg

  mandatory Engine
  XOR Gasoline                         0 EUR    200     Kg
  XOR Diesel                        3000 EUR    300     Kg
  …
```


bmw-dribbble.jpg
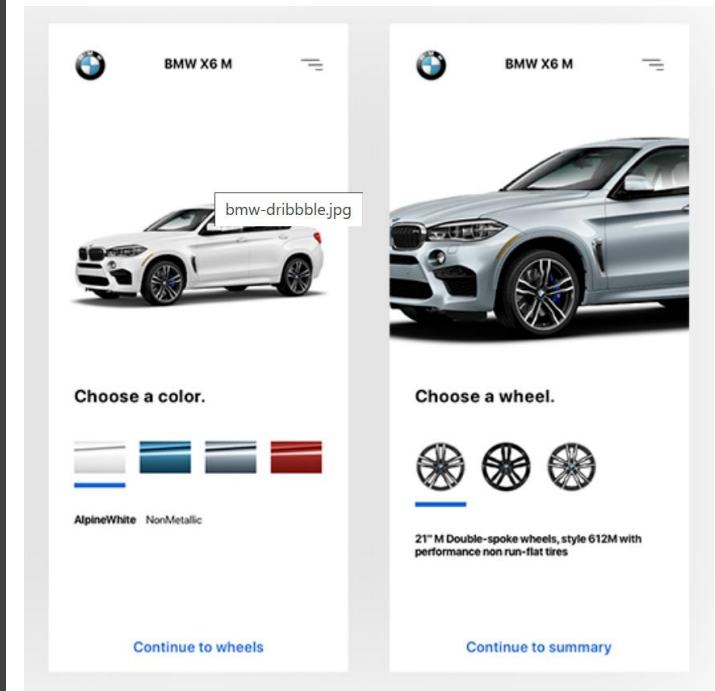
Example. Residential Solar Generation

```
Residential Photovoltaic Installation
  mandatory Installation                                    Base 4000 EUR
  mandatory Inverter
    XOR Model A                       Generation 4000 kWh   2300 EUR
    XOR Model B                       Generation 5000 kWh   2500 EUR
    XOR Model C                       Generation 6000 kWh   2900 EUR
  mandatory Generation Units (1..20)
    XOR Panel-A1 Generation 400 W  Size 200 x 100 x 5 cm     300 EUR
    XOR Panel-A2 Generation 450 W  Size 210 x 100 x 5 cm     350 EUR
    XOR Panel-A3 Generation 550 W  Size 220 x 100 x 5 cm     400 EUR
  optional Batteries (0..20)
  optional Battery-M1 Capacity:  5 kWp
  optional Battery-M2 Capacity: 10 kWp
  optional Battery-M3 Capacity: 15 kWp
  optional Extended Warranty
    XOR 5 years                                             2000 EUR
    XOR 10 years                                            3000 EUR

constraint: Inverter.Capacity >= sum(panel.Capacity)
```

Example. PLD/Miura 5 Configuration

```
Rocket Miura-5         Height: 35.7 m  Max Weight: 69.025 Kg
mandatory Phase-1      Height: 26.3 m
mandatory Engine TEPREL-C (5..5)                    190 kN
    mandatory Tank1           Propelent: LOX
    mandatory Tank2           Propelent: Biokerosene
   mandatory Phase-2  Height: 12.1 m
   mandatory Engine                    50 kN
   mandatory Payload
      XOR Payload-Config-1 1 L Satellite
      XOR Payload-Config-2 2 S Satellites
      XOR Payload-Config-3 1 L Satellite,
          1..4 XS Satellites

Constraint: Payload max. 450 kg
```
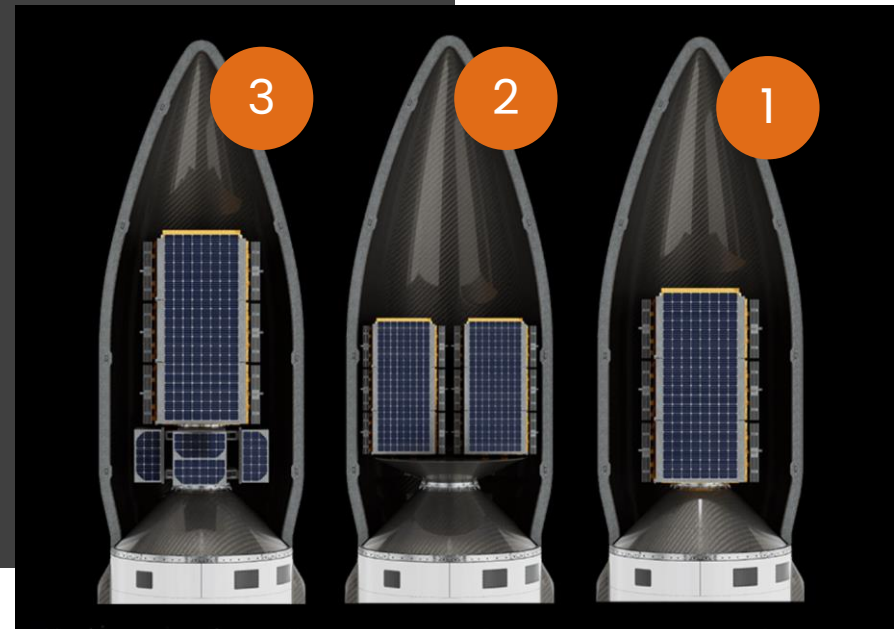
Feature Models in Space Missions

- **Central asset** to assemble subsystems into bigger systems

- Allow reuse of subsystems from previous missions (already tested)

- **Reuse** knowledge & assets

- **Controlled risks** on selected new subsystems

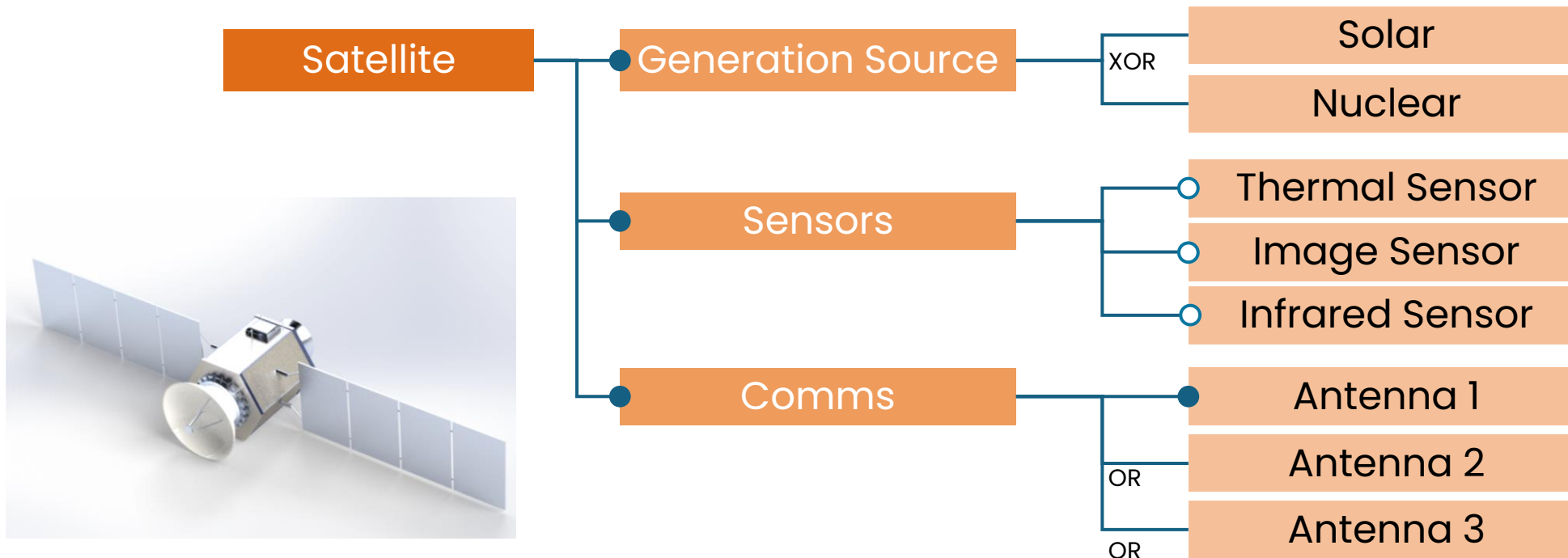- Can upgrade as the technology evolves: new materials/technologies

Phases & Use Cases

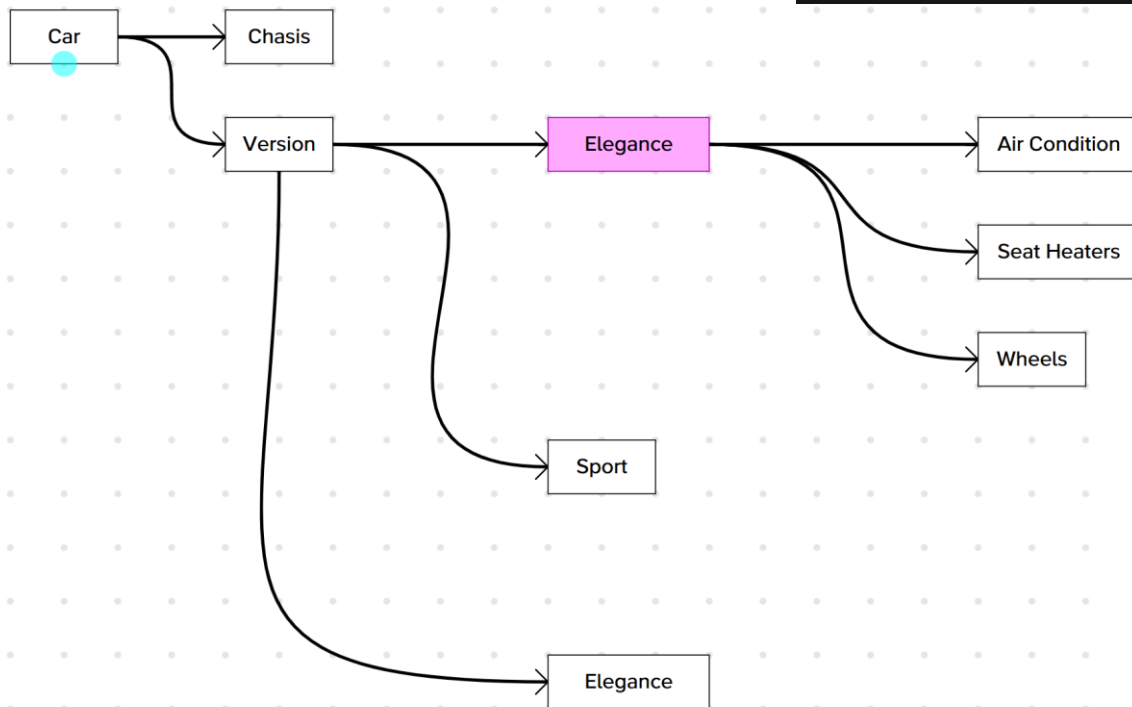1. Feature Modeling-Time

2. Mission Design-Time

3. Operation-Time

Phase 1. **Feature Modeling-Time**

- Design the family of products, constrains and operational limits.
- Define variants and limit options.

Phase 1. **Feature Modeling-Time**

Projectional Notation

FEATURE
Name: Chasis
Description: Base Chasis
Cardinality: Mandatory

PROPERTY VALUE
Name: Weight
Value: 1500

FEATURE
Name: Version
Description: Version
Cardinality: XOR

FEATURE
Name: Elegance
Description: Version Elegance
Cardinality: Optional

FEATURE
Name: Air Condition
Description: Air Condition
Cardinality: Optional

PROPERTY VALUE
Name: Weight
Value: 2

PROPERTY VALUE
Name: Price
Value: 2000

FEATURE
Name: Seat Heaters
Description: Seat Heaters
Cardinality: Optional

PROPERTY VALUE
Name: Price
Value: 500

PROPERTY VALUE
Name: Weight
Value: 1

FEATURE

Graphical Notation

Car → Chasis

Version → Elegance → Air Condition

Elegance → Seat Heaters

Elegance → Wheels

Version → Sport

Version → Elegance

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Phase 2. **Mission Design-Time**

- Instantiates a concrete exemplar of the FM for a selected mission
- Check constrains, trace to requirements

Questions:

Are all the required sensors on board?

Is the payload weight valid?

What color would you like for your car?

Phase 2. **Mission Design-Time**

FEATURE	SELECT	WEIGHT (KG)	PRICE (EUR)	DESCRIPTION
Chasis	selected	1500	-	Base Chasis
- Version	XOR	-	-	Version
- Elegance	☑ selected	-	30000	Version Elegance
Air Condition	☑ selected	2	2000	Air Condition
Seat Heaters	☐ select	1	500	Seat Heaters
+ Wheels	selected	-	-	Wheels
Sport	☐ select	-	40000	
Advance	☐ select	-	50000	
Total:		**1,502**	**32,000**	

Phase 3. **Operation-Time**

- Tracks system and subsystem with abundant telemetry for data analytics & operations → Ground Control Systems, Digital Twins
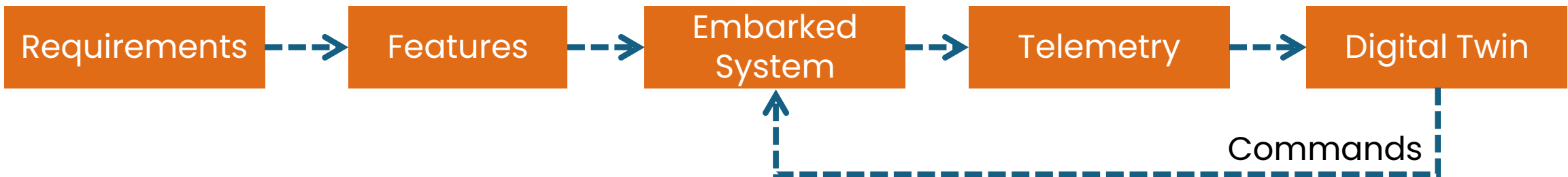
Questions:

Are the solar panels producing energy as expected?
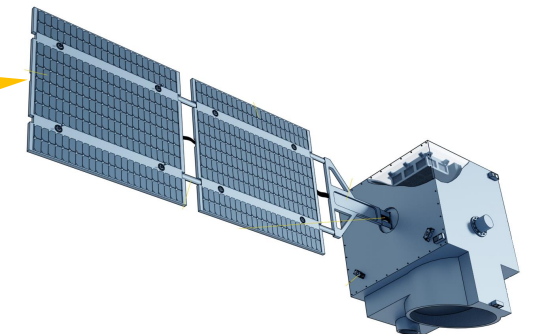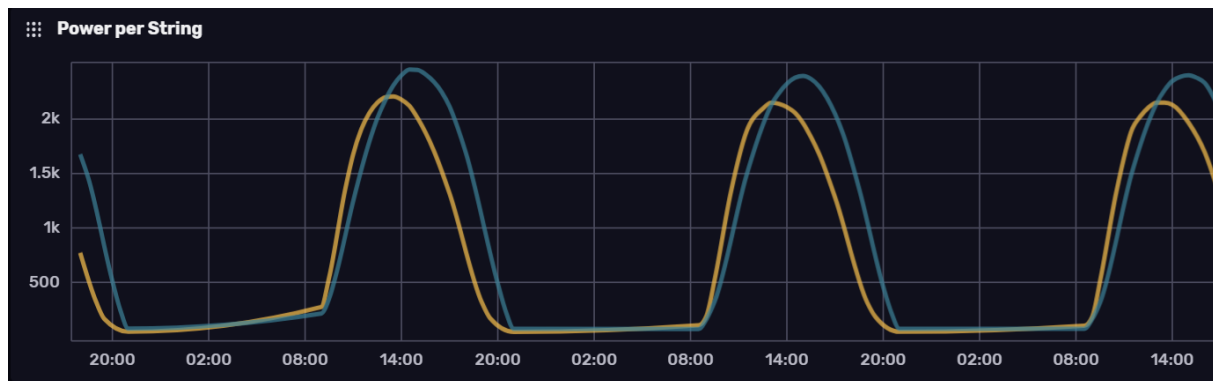
Conclusions

- Feature Modeling are applicable for many domains
- FM are a must for Space Missions (a long tradition)
- Better tools (UX) for FM are possible
- Better traceability from reqs. to operations (Digital Twins)

Requirements → Features → Embarked System → Telemetry → Digital Twin

Commands

Conclusions

- Same concepts, same language, better understanding.

- **Reuse** of subsystems already tested from previous Mission.

- **Extensible to incorporate** new technologies/artifacts when they are available.

Thanks! Q&A

Try them at:

https://fm.metadev.pro

https://essential.metadev.pro

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